IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of		Dated:	June 21, 2009
	Colin C. DAVIS	HP Docket No.:	10003590-1
Serial No.:	09/761,287	Confirmation No.:	5570
Filed:	January 16, 2001	Examiner:	Danton D. DEMILLE
For:	THERMAL GENERATION OF DROPLETS FOR AEROSOL	Group Art Unit:	3771

Mail Stop AF
Commissioner for Patents
P. O. Box 1450
Alexandria, Virginia 22313-1450

Sir:

DECLARATION UNDER 37 C.F.R. § 1.131

I declare as follows:

1. I am the named inventor on the above-identified U.S. patent application. At the time of invention, I was an employee of Hewlett-Packard Company.

2. Prior to April 27, 2000, the filing date of the earliest application from which U.S. Pub. No. 2004/0016427 to Byron et al. ("Byron") claims priority, I conceived and reduced to practice the methods recited in independent claims 7 and 15, as demonstrated generally by an HP Invention Disclosure (Exhibit 1) and a laboratory notebook page (Exhibit 2), which are attached to this Declaration.

3. Exhibits 1 and 2 generally demonstrate the conception and reduction to practice, prior to April 27, 2000, of a method of generating droplets, as recited in claim 7. The method of claim 7 includes providing a supply of liquid, configuring liquid-holding chambers to include orifices such that liquid that is propelled from the chambers passes through the orifices along a trajectory, filing the chambers with some of the liquid, providing a planar heat transducer in each chamber, the planar

heat transducer being oriented in a plane substantially perpendicular to the trajectory of the propelled liquid, instantaneously heating the liquid in the chambers by an amount sufficient to produce a vapor bubble in each chamber for propelling liquid from each chamber, and sizing the heat transducer relative to the chamber such that the liquid that is propelled from the chamber separates to form droplets, wherein each droplet has a volume of less than 100 femtoliters.

4. Exhibits 1 and 2 also generally demonstrate the conception and reduction to practice, prior to April 27, 2000, of a method of generating droplets, as recited in claim 15. The method of claim 15 includes providing a supply of liquid, filling chambers with some of the liquid, providing a planar heat transducer within each chamber, instantaneously heating the liquid in the chambers by an amount sufficient to produce a vapor bubble in each chamber that propels the liquid from the chamber through an orifice and along a trajectory, and orienting the planar heat transducer in a plane that is substantially perpendicular to the trajectory and spaced sufficiently near the orifice so that the propelled liquid separates into two or more droplets upon exiting the orifice.

5. Exhibits 1 and 2 also generally demonstrate the conception and reduction to practice, prior to April 27, 2000, of the methods, as recited in claims 9, 10, 13 and 14, which depend from claim 7, and of the method, as recited in claim 16, which depends from claim 15.

6. All acts set forth herein and/or relied upon for the purpose of establishing invention were carried out in the United States, a NAFTA country other than the United States, or a WTO member country other than a NAFTA country.

7. I declare that all statements made herein of my knowledge are true and that all statements made herein on information and belief are believed to be true. These statements were made with the knowledge that willful false statements, and the like so made, are punishable by fine or imprisonment or both under § 1001 of Title 18 of the United States Code. I understand that such willful false statements may jeopardize the validity of the application or any patent issuing therefrom.

Date: 6/22/09

Colin C. Davis

INVENTION DISCLOSURE

(WKRP document: 20000420.092645)

HEWLETT PACKARD

PDNO: *10003590* [redacted] ATTORNEY: [redacted]

***Instructions:** The information contained in this document is **HP** CONFIDENTIAL and may not be disclosed to others without prior authorization. Submit this disclosure to the HP Legal Department as soon as possible. No patent protection is possible until a patent application is authorized, prepared, and submitted to the Government.*

Initial Information

Descriptive Title of Invention:

Method for Producing Femtoliter Scale Aerosal Drops Through Explosive Drop Ejection

Brief Abstract of Invention: **(Please write a brief description of the fundamental invention.)**

It has been found that liquid drops with diameters of around 4 m (33.5 femtoliters) can be absorbed by the lung's alveoli. Producing liquid drops of this size scale enables drug delivery through the use of inhalers that has potential to replace hypodermic medicine delivery. This disclosure describes a method to produce this scale of aerosal through "explosive" clearmode TIJ drop ejection and showerhead designs.

Name of Project:

Medical Inhaler

Product Name or Number:

[redacted]

Invention History

[redacted]

Was the invention described in a lab book or other record? If so, please identify (lab book #, etc.):

Yes. - lab book 10765 [redacted]

[redacted]

Exhibit 1

Description of Invention
Please preserve all records of the invention and attach copies
A. Prior solutions and their disadvantages:(if available, attach copies of product literature, technical articles, patents, etc. as attached files in the "Additional Information" section below.)
see attached description
B. Problems solved by the invention:
see attached description
C. Advantages of the invention over what has been done before:
see attached description
D. Description of the construction and operation of the invention:(include appropriate schematic, block, & timing diagrams; drawings; samples; graphs; flowcharts; computer listings; test results; etc. as attached files in the "Additional Information" section below.)
see attached description

Party(ies) Involved

Inventor(s):Pursuant to my (our) employment agreement, I (we) submit this disclosure.

Employee Number	Name	Telnet	Location Code
[redacted]	*CHRIS DAVIS*	[redacted]	[redacted]

Witness(es):The invention was first explained to, and understood by, me (us) on the following date(s):

Employee Number	Name	Telnet	[redacted]
[redacted]	[redacted]	[redacted]	

Additional Information

[redacted]

Exhibit 1

Method for Producing Femtoliter Scale Aerosal Drops Through Explosive Drop Ejection

Chris Davis

[redacted]

It has been found that liquid drops with diameters of around 4μm (33.5 femtoliters) can be absorbed by the lung's alveoli. Producing liquid drops of this size scale enables drug delivery through the use of inhalers that has potential to replace hypodermic medicine delivery.

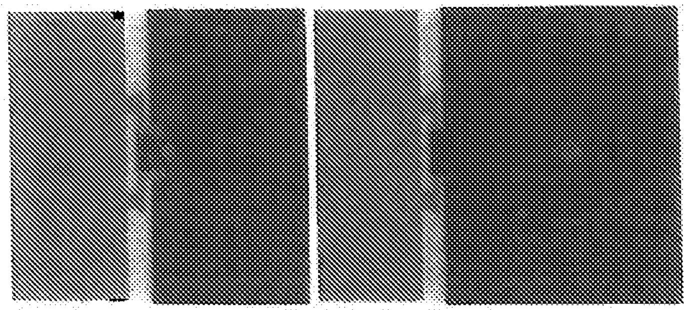
Liquid drops on the order of femtoliters can be produced through micro-scale fluid channels and mechanical actuators such as high pressure vapor bubbles produced with thinfilm resistor heaters. These fluid channels and actuators can be fabricated using micromachining techniques similar to those used for ejecting drops from inkjet printheads. It has been shown that these micromachined drop ejectors can be designed to produce drops over a range of volumes.

One method to produce very small aerosol drops with these techniques is to tune the geometry of the individual drop generators such that the ejected drop breaks into more than one smaller drops per firing chamber. The alternative method is to produce very small chambers that produce single 4μm diameter drops per chamber. This would require very small heater resistors and chamber geometries that would be very thermally inefficient and hard to fabricate. Breaking what would be a larger drop into several smaller drops enables greater thermal efficiency since only one activation of the heater resistor generates more than one femto-scale drop reducing the duty cycle of the device. The larger chamber also allows for easier fabrication. This disclosure describes a method and several examples of embodiments to generate femto-scale drops for this application.

One design technique that could be used to beak drops into smaller ones uses the high-pressure vapor bubble to evacuate the firing chamber and break the ejected meniscus into several parts. This can be accomplished by fabricating a thin chamber geometry relative to the resistor size which can be represented by the dimensionless parameter T/R where T is the chamber thickness and R the square root of the resistor area. Having a very small T/R ratio ensures an explosive drop ejection that breaks the ejected liquid meniscus into several drops smaller than the volume of the chamber. Figure 1 shows results from a Computational Fluid Dynamics simulation where a firing chamber geometry with a T/R of 0.36 was modeled. This simulation produced 3 x 33fL drops for one firing chamber with one nozzle. Note that the flight trajectory of these drops would not be considered acceptable for inkjet applications, but should not matter for medical inhaler applications.

[redacted]

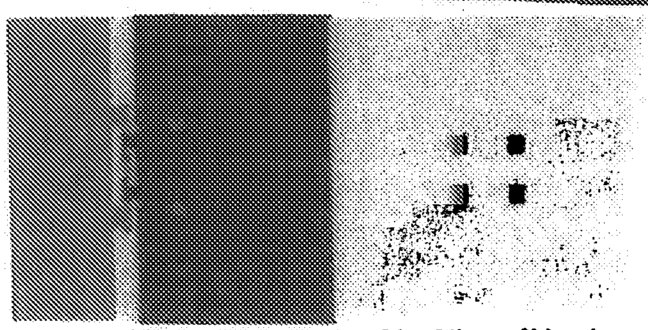
Exhibit 1



0.5μsec 2μsec

Figure 1 - CFD Results of Explosive Drop Ejection (single nozzle) Resulting in 3 x 33fL Drops

Another design technique that would enable these drop size requirements while maintaining sufficient thermal efficiency is to combine multiple nozzles per chamber with a low T/R ratio. This forces multiple small drops to be ejected from one chamber. Figure 2 shows results from another CFD simulation of drops ejected from multiple nozzles on one chamber. [redacted]



Profile View Plan View of Nozzles

Figure 2 - CFD Results of Explosive Drop Ejection (multi-nozzle) Resulting in 4 x 32fL Drops

<u>Advantages over other Aerosol generating Concepts</u>

Other ideas to generate aerosol of this size scale use thermal inkjet (TIJ) technology to meter the flow while using other means to breakup the large drops including vibrating piezoelectric elements and RF fields. The methods described in this disclosure require only the TIJ technology to meter and breakup the ejected drops. This lowers complexity, product cost, and energy requirements.

Ultra small firing chambers could also be used to eject *single* femto-scale drops. Ejecting very small single drops have at least 3 disadvantages:

Exhibit 1

1) Since only one drop would be ejected per firing, the heater resistors are required to be fired several times to achieve the same flux as a chamber ejecting several drops per firing. This higher duty cycle lowers reliability and increases the thermal load of the system.
2) Single drop ejection of this scale would require *very* small critical dimensions increasing the difficulty of fabrication. For example, a resistor size of ~2x2um would be very difficult to make and control using conventional TIJ processes, specifically, slope metal etch.
3) Very small resistors are also less thermally efficient. It has been shown that resistors below Xum2 are dominated by heat lost through the periphery making consistent superheated vapor nucleation difficult.

Exhibit 1

18

Project No.
Book No.
TITLE [illegible]

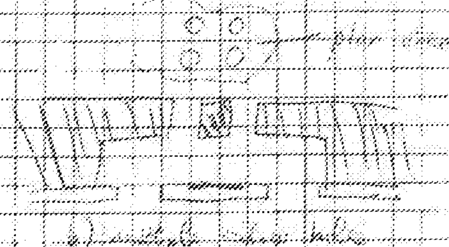
From Page No.

[illegible]

[illegible]

Example:

[redacted]



To Page No.

Witnessed & Understood by me,
[redacted]
Invented by [illegible]
[redacted]
Recorded by

TITLE
Project No.
Book No.

From Page No. 18

[illegible]

To

Witnessed & Understood by me,
[redacted]
Invented by [illegible]
[redacted]
Recorded by

Exhibit 2